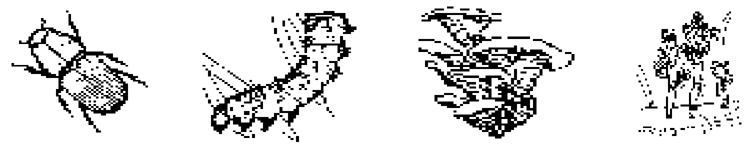
Forest Health Protection



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DOUGLAS-FIR BEETLE SURVEYS OF THE FIRES OF 2000 IN THE NORTHERN REGION FOREST HEALTH PROTECTION SPRING 2003

Beverly M. Bulaon

INTRODUCTION

In 2000, over one million forested acres in western Montana and northern Idaho were burned by wildfires. The intensity and severity of fires varied across the landscape, but stands that experienced only low to moderate intensity burns became subsequently susceptible to mortality from other damaging agents, such as bark beetles. Stands only marginally attractive to beetles prior to fires were now much more susceptible to infestation.

Surviving Douglas-fir trees that experience low to moderate intensity burns are particularly attractive to Douglas-fir beetle (*Dendroctonus pseudotsugae* Hopkins) for several years after a fire (Furniss 1965). Because beetles respond quickly to stand disturbances such as fire or blow-down, populations can rapidly build and expand beyond endemic levels due to the sudden abundance of susceptible host material (Furniss et al*.* 1979). Thus tree mortality as a consequence of wildfires may linger after the initial disturbance. Trees adjacent to fire perimeters, and surviving trees from fires of 2000 were likely to be attacked by Douglas-fir beetles in 2001 and a few years afterward.

Following the fires of 2000, assessment of Douglas-fir beetle hazard was needed to determine what the extent and level of beetle populations were in and near burned areas (FHP 2002). Personnel from Forest Health Protection in the Northern Region initiated a survey during the summer of 2002 to assess Douglas-fir beetle presence in several burned areas on national forests in Montana and northern Idaho. Information relative to current mortality and beetle population levels can assist in developing management strategies to help reduce future tree mortality.

The main objectives of the project were to:

1. Develop information to determine tree mortality associated with and subsequent to the fires of 2000.
2. Project the potential for future bark beetle-caused mortality in Douglas-fir stands in and near burned areas.
3. Compare survey results with risk predictions from 2001 fire assessment.
4. Assess information and propose ways to reduce bark beetle effects.

United States Department of Agriculture | Forest Service | Northern Region | 200 East Broadway, P.O. Box 7669, Missoula, MT 59807

Beetle Biology

Douglas-fir beetles are small dark brown to black beetles, which burrow under the bark of their preferred host, Douglas-fir (Schmitz and Gibson 1996). This native bark beetle functions as a thinning agent removing weak, diseased, or over-mature trees. Adult beetles are most active in early spring, when they emerge and seek suitable hosts to lay their brood. Larvae rapidly develop a couple of weeks after egg emergence, feeding in the phloem layer of host trees. Broods usually complete development to adult stage before overwintering under the bark, but some remain as larvae. Douglas-fir beetle life cycle typically requires only one year for complete development from egg to adults (Schmitz and Gibson 1996).

Although there is no validated hazard rating system for Douglas-fir beetle following fires at present, stand conditions conducive to outbreak development are known. Areas determined most hazardous are those that have favorable stand characteristics as well as suitable hosts. Hazardous conditions after a fire are: Douglas-fir constituting a high percentage of the stand, surviving Douglas-fir of large diameter with light to moderate scorch, and fairly high basal area – more than 120 ft^2/acre (Furniss 1965). Douglas-fir mortality due to bark beetles is correlated with high proportions of Douglas-fir in a stand (Furniss et al. 1979) and increasing basal area (Negron et al. 1999).

SURVEY CRITERIA AND METHODS

Near outbreak conditions prior to 2000 resulted in epidemic levels of Douglas-fir beetle in and around burned areas the following year. District personnel were concerned about increasing mortality associated with recent infestations as well as additional loss if beetle populations continued to build and expand beyond fire perimeters. Ground surveys were conducted in selected fires to determine the status of current beetle populations and their potential for spread into bordering green stands.

The wildfires considered for survey were first selected by the following criteria: greater than 1,000 acres being National Forest land, species composition of at least 10 percent Douglas-fir, more than 50 percent of the area near roads, stand data available for the burned area, and cooperation with district personnel to provide support and stand data. Roadless and wilderness areas were generally excluded due to lack of access. A buffer of 1 mile beyond selected fire perimeters was included to assess adjacent green stands – areas where beetles are likely to infest in subsequent years.

Once fires were selected, burn severity data was compiled to locate areas where some trees had survived. Potential survey areas were prioritized by burn intensity categories using the following table (Table 1). These categories assisted in selecting areas of highest susceptibility based on amount and level of burn intensity.

Table 1. Burn intensity classes based on “Tree Survivability,” October 2000 (FHP 2000)

Burn Intensity (BI) Classes	Description
BI 1	All vegetation blackened, foliage destroyed, boles deeply charred and understory vegetation burned. Approximate distribution of ground char: Unburned 0%, Light 15%, Moderate 70%, Deep 15%
BI 2	Stem predominantly blackened, some foliage only scorched. Understory vegetation mostly burned. Ground char: Unburned 0%, Light 25%, Moderate 60%, Deep 15%
BI 3	Most vegetation scorched with few blackened stems; small amounts of green vegetation. Ground char: Unburned 0%, Light 40%, Moderate 50%, Deep 10%
BI 4	Predominantly, but temporarily green with scorched or blackened areas. Ground char: Unburned 0%, Light 40%, Moderate 50%, Deep 10%

Areas in BI1 were eliminated because severely charred trees have no live cambium. Trees in BI classes 2 and 4 are dependent upon the amount of bole and root collar damage, respectively. While trees in either class are possibly susceptible, the combination of areas for survey was overwhelming. Efforts focused on BI3 areas since those had the greatest likelihood of experiencing beetle attacks. In this class, fire damage weakened trees’ defense mechanisms, but phloem was still adequate to provide beetle habitat. According to Furniss (1965), trees with light and medium damage to the cambium received more attacks than those with heavier damage. Aerial and ground survey data were then examined to locate beetle activity inside or within ½ mile from fire boundaries that could be sources of incoming beetles. Ground survey locations were randomly selected from areas designated BI3, with the intent of surveying at least 10 percent of the susceptible area.

Next, fires were selected by the proportion of total burned area to areas of moderate and high susceptibility to Douglas-fir beetle. Stands within and surrounding each selected fire were prioritized by a Douglas-fir query system (Randall and Tensmeyer 1999), which utilized known hazard parameters filtered past stand exam data (R1-edit) or stand summary information stored in Timber Stand Management Record System (TSMRS). Stands determined moderate to high hazard were chosen.

Field crews began surveying stands in late May. Surveys were completed in October 2002. Walkthrough surveys were conducted in many stands, but FINDIT[1] plots established only where Douglas-fir beetle activity (past or current year attacks) was observed in groups of three trees or more in close proximity. Tree groups were at least three chains apart with enough activity to establish a minimum of two plots, no more than ten. After scouting a selected stand, approximations of infestation size were mapped and plot transects established to cover most of the infested area. Plot locations were mapped and recorded by GPS. Species, diameter-at-breast height (inches), and damage code were collected for trees as determined by a 20 basal area factor prism and a breakpoint diameter of 5 inches. Damage codes identified whether trees were burned, attacked, or still healthy (Table 2).

[1] Data analysis using FINDIT (Forest Insect and Disease Tally System)(Bentz 2000) determined presence, extent, and current activity levels of Douglas-fir beetle in surveyed areas within and adjacent to fire perimeters.

Table 2. FINDIT codes.

Code number	Description
0	Undamaged, live tree
1	Older attack, dead tree
2	Current attack, dead tree
3	Last year attack, dead tree
4	Burned and older attack, dead tree
30	Burned, last year attack, dead tree
31	Burned, current year attack, dead tree
32	Burned only, live tree

RESULTS

Crews conducted surveys in 13 fires on 7 national forests in Montana and northern Idaho that burned in 2000 (Table 3). Priority acres are those areas rated with BI3 – areas that experienced light scorch on tree stems and partial understory vegetation burn. A total of 332 stands inside and outside fire perimeters were surveyed.

Table 3. Summary of fires surveyed in 2002.

National Forest	Fire Name	Acres within Fire Perimeters	Priority Acres	Acres Surveyed
Beaverhead-Deerlodge	Mussigbrod	43,705	3,247	1,247
Bitterroot	Blodgett Trailhead	11,472	657	657
Clearwater	Crooked	4,881	1,407	398
Clearwater	Elizabeth	3,276	747	16
Helena	Cave Gulch	29,307	2,697	1,269
Helena	Maudlow-Toston	81,797	3,668	2,059
Kootenai	Cliff Point	6,586	2,837	491
Kootenai	Lydia Mountain	5,895	668	551
Kootenai	Stone Hill	11,120	2,243	881
Lolo	Flat Creek	9,467	2,656	435
Lolo	Landowner Mountain	5,905	2,074	753
Lolo	Ninemile	19,910	3,971	1,452
Nez Perce	Burnt Flats	22,530	2,5236	665

2002 Ground survey results and discussion

Moderate to high hazard stands for Douglas-fir beetle attack were intentionally selected for surveys because of expected beetle attraction into those areas. Locations with high average composition of large diameter Douglas-fir became infested immediately after fires, as anticipated. Prior conditions of stand basal area and average stand d.b.h. most often were at the upper end of high to moderate standards for beetle prevention. Fire damage only increased the possibility of bark beetle attack in stands of any susceptibility. If populations of Douglas-fir beetle populations continue to build, less susceptible stands may be infested due to high beetle pressure.

Data analysis using FINDIT conveyed the following results for surveyed fires (Table 4). Data presented are from plots only *within* fire perimeters. Due to time constraints and volume of BI3 acres to be surveyed, buffer areas ranked as low priority. Exceptions were some surrounding areas around the Cave Gulch fire, which had heavy infestations along the perimeter. Analysis of FINDIT plots for these buffer areas show very heavy mortality in green trees of medium to large diameter classes leaving only 50 percent or less of those sizes. Mortality of this magnitude is anticipated to occur in surrounding green trees if currently high infestation areas continue to expand.

The average total of attacked trees in 2002 was five times greater than 2001 (361 compared to 70). The number of trees per acre attacked in both years ranged from 15 to 52 (Table 4). Number of attacked trees tended to increase proportionately with the number of fire-damaged Douglas-fir in the stand. Most beetle attacks were focused on fire-damaged trees. The majority of fires (7 out of 13) had 40 percent to 50 percent of the fire-damaged Douglas-fir attacked by bark beetles in 2001 and 2002. Ten of the thirteen fires had 30 percent to 50 percent attacked. Douglas-fir beetle attacks in fire-injured trees increased significantly for most fires from 2001 to 2002, except the Crooked fire which was already heavily attacked in 2001. There are only five fires with slightly over 50 percent fire-damaged trees remaining. Trees without fire damage were scarce within fire perimeters, but a few attacks were recorded.

Much of the mortality in 2001 and 2002 was large diameter Douglas-fir. Douglas-fir beetle consistently selected the largest fire-injured trees in all surveyed areas (Table 5). In 2002, most attacked trees were 15+ inches while a few fires experienced attacks in mid-range diameter (9 inches to 14.9 inches) trees. Attacks were also found on smaller diameter trees indicating a high level of beetle pressure in the area. While attack incidence typically increases with tree diameter, smaller trees with fire damage are still attractive (Furniss 1965). Where small diameter (9” or less) trees were attacked, many larger diameter trees had already been infested and preferred-size hosts depleted. Although a fair percentage of non-attacked Douglas-fir remains in all fires, most are small diameter.

In these surveyed areas, Douglas-fir beetle populations have killed significant amounts of surviving fire-injured trees during the past two years. However, anticipated mortality for 2003 is expected to decrease for all locations (Table 4). These predictions were determined by comparing the number of currently infested trees against those not attacked. While percent mortality (the number of beetle-attacked trees from all live trees per acre in a given year) may remain high, the actual loss (number of trees) will be lower in 2003. Much of the large diameter Douglas-fir has been depleted in surveyed areas, leaving smaller or less suitable trees as potential hosts. Fires such as Mussigbrod, Blodgett, Stone Hill, Ninemile, and Burnt Flats still retain high percentages of live trees per acre, but much of those trees are below 10 inches in diameter. Smaller trees equate to fewer brood produced and higher rates of cold-weather desiccation. Suitable sized trees remaining within fire perimeters are few, implying that beetle populations will decline quickly.

Table 4. Summary of Douglas-fir beetle-caused mortality in surveyed fires ending October 2002–does not include older or unknown mortalities. Values are estimated trees per acre over 11 inches d.b.h.

Fire Name	Fire damaged non-attacked	Fire damaged 2001 attacks	Fire damaged 2002 attacks	Total live basal area (ft^1/acre) 2002*	Anticipated DF mortality trend
Mussigbrod	26.3	1.17	17.50	38.8 (48%)	Decreasing
Blodgett-Trailhead	68.0	0	52.46	50 (56%)	Decreasing
Crooked	14.2	15.62	16.11	36.7 (32%)	Decreasing
Elizabeth	12.7	11.03	15.45	50 (32%)	Decreasing
Cave Gulch	18.8	4.34	19.24	66.2 (44%)	Decreasing
Maudlow-Toston	35.2	2.64	46.80	45 (42%)	Decreasing
Cliff Point	15.9	11.64	33.37	33.7 (26%)	Decreasing
Lydia Mountain	25.3	3.11	44.15	58.8 (35%)	Decreasing
Stone Hill	32.9	3.56	19.78	70 (58%)	Decreasing
Flat Creek	27.1	3.52	30.22	34.8 (45%)	Decreasing
Landowner	29.4	12.49	38.27	57.8 (37%)	Decreasing
Ninemile	27.8	4.63	17.59	49.9 (56%)	Decreasing
Burnt Flats	17.1	5.76	9.83	87.6 (52%)	Decreasing

[1]Remaining live trees from total trees per acre are included as percentages.

Table 5. Summarized FINDIT results of Douglas-fir QMD[1] in surveyed stands.

Fire Name	QMD of undamaged Douglas-fir	QMD of fire-injured Douglas-fir	QMD of fire-injured attacked Douglas-fir in 2002
Mussigbrod	0	16.0	22.6
Blodgett Trailhead	0	12.8	13.3
Crooked	21.8	19.6	23.1
Elizabeth	0	12.0	20.8
Cave Gulch	12.0	12.2	16.7
Maudlow-Toston	16.8	14.1	16.2
Cliff Point	0	14.1	17.4
Lydia Mountain	0	12.7	18.3
Stone Hill	0	12.0	20.3
Flat Creek	0	11.0	18.9
Landowner	0	14.2	16.8
Ninemile	0	15.0	17.7
Burnt Flats	24.0	21.6	25.2

[1]QMD is quadratic mean diameter.

Predictions and outcomes from 2001

In the fire assessment of 2001[2], Forest Health Protection in Region 1 estimated potential Douglas-fir beetle levels for selected fires in 2000 for national forests in Idaho and Montana. These predictions were based on insect mortality detected from aerial flight surveys in 1999 and 2000. While predictions were broad in scope, they provided an indication that areas surrounding burned stands were at risk to expanding beetle populations. Areas designated "1" were areas where beetle populations were detected nearby, while "2" indicated those populations were building or already at outbreak levels. Estimates were given so restoration prescriptions could consider strategies to prevent additional mortality. Below (Table 6) are the ratings of the fires surveyed in 2002, and the increase in Douglas-fir beetle attacked trees from 2001 to 2002.

Comparing the beetle-caused mortality in 2002 with 2001, Douglas-fir beetle predictions were most often accurate. Where Douglas-fir beetle populations were present in or nearby at-risk areas in 2001, beetle populations expanded considerably in 2002. However, predictions did not include the intensity of beetle pressure and stand conditions. Two fires, Mussigbrod and Ninemile, suffered heavier mortality than expected. Also, predictions were largely based on current beetle activity in the vicinity of susceptible stands. Initiating populations immediately after a disturbance cannot be estimated until the following year. The 1999 aerial survey of Maudlow-Toston, Cave Gulch, and Blodgett Trailhead areas showed no beetle activity in these areas previously, but were all significantly attacked after the fires.

MANAGEMENT ALTERNATIVES

Stand attributes strongly influence development of Douglas-fir beetle populations. However, they are not the only factors that contribute to overall stand susceptibility and beetle activity. Land managers should be aware of the current situation and possibility of further mortality if prevention or suppression strategies cannot be applied. Surveys in selected fires indicate that beetle populations may subside in the near future as preferred host availability has run low and beetles are resorting to small diameter hosts (Ken Gibson, *personal communication* 2002).

Besides stand characteristics, Douglas-fir beetle populations are also dependent on climatic conditions – mild winters with above average temperatures allow higher survival rates for next year's brood while extremely cold temperatures for even a few weeks can decimate populations considerably (Atkins and McMullen 1958). Douglas-fir beetle outbreaks in standing trees usually last between 2 to 4 years (Schmitz and Gibson 1996), but this can vary greatly depending on weather. Consequently, tree mortality may continue if host is still available and weather is favorable to brood survival. Currently infested Douglas-fir trees will provide brood for next year's attack; therefore all susceptible trees still have good likelihood to be targeted if weather remains favorable. Infestations can spread through remaining "green islands" and into adjacent unburned stands unless mitigation efforts are implemented. As beetle pressure increases, even less suitable hosts may be attacked. When disturbances such as fire or windthrow occur, prompt removal of potential hosts greatly reduces susceptibility to Douglas-fir beetle attack.

[2] An Assessment of the 2000 fire season in the Northern and Intermountain Regions, January 2001.

Table 6. Surveyed fires and their current Douglas-fir beetle levels.

National Forest	Fire Name	Predicted DFB levels for 2002	Attacks 2002:2001
Beaverhead-Deerlodge	Mussigbrod	1	15x
Bitterroot	Blodgett Trailhead	NA*	50x
Clearwater	Crooked	1	1x
Clearwater	Elizabeth	1	1.5x
Helena	Cave Gulch	NA*	6x
Helena	Maudlow-Toston	NA*	18x
Kootenai	Cliff Point	2	3x
Kootenai	Lydia Mountain	2	15x
Kootenai	Stone Hill	2	6x
Lolo	Flat Creek	2	10x
Lolo	Landowner Mountain	2	3x
Lolo	Ninemile	1	4x
Nez Perce	Burnt Flats	2	2x

*No prediction was made due to lack of detailed data.

There are management alternatives that can be implemented during infestation periods. Possible strategies for control are cited from Gibson (2001):

1. Salvage of currently infested trees can prevent and slow down beetle spread into green trees. Trees need to be removed before next year's brood can emerge – usually by early April, and no later than mid-May.

2. Trap trees can be either cut prior to beetle emergence or left standing and baited with pheromone tree baits to attract emerging beetles. Either requires removal of these trees after they are attacked and before beetle flight, with the potential of a few "spill over" attacked trees. The number of trap trees (two attractant baits per tree) is dependent on the infestation size but should be sufficient to attract most incoming beetles. If the commitment to remove trap trees before beetle emergence cannot be made, then they should not be installed. Failure to do so would only exacerbate the situation.

3. Baited funnel traps can "trap out" small, isolated populations. Not useful for large, widespread populations, but can be effective in some situations now existing. They may not be effective as trap trees or salvage, and there is the possibility of some nearby trees being attacked, but they are the least expensive and cause minimal site disturbance. Traps need to be installed about mid-April and emptied every week afterward until beetle catches cease. Traps and attractant lures are commercially available at a cost of about $40 per set.

4. Under varying circumstances, attacks can also be prevented using an anti-aggregant pheromone labeled MCH (methylcyclohexa-none). MCH bubble caps are used at a rate

of 30 per acre and are also commercially available at about $1.50 per capsule. Research has shown MCH effectively reduces Douglas-fir beetle-caused mortality in high-risk areas.

5. While these control methods can reduce further mortality, the option “No action” must also be considered. Under this alternative, the potential for beetle populations increasing and killing additional large-diameter Douglas-fir in nearby susceptible stands is high. The amount of standing mortality corresponds to the number of high hazard stands in the general vicinity of ongoing epidemics. Land managers must determine what can be viewed as acceptable mortality, impacts with other habitats and species, and how long mortality can be accepted to perpetuate if this is the decided strategy.

“Action” treatments should be applied where appropriate, and when they can be the effective. While these options maybe recommended and perform well in application at low endemic levels, they may still not prevent all future attacks. Forest Health Protection personnel will gladly provide any supplemental information on management alternatives as well as purchasing products and applying treatments.

Prevention is the most effective strategy to forestall most bark beetle-caused mortality. Maintaining vigorous healthy stands and altering stand conditions that favor population build-up greatly reduce the likelihood of heavy infestations. Stand conditions regulated to keep hazard in the low to moderate range will result in optimal tree growth and vigor, and less attraction to pioneer beetles. The following guidelines on regulating Douglas-fir stand hazard were taken from Gibson et al. (1999):

1. Stands in which Douglas-fir is predominant and sites on which those stands are most commonly found. Higher percentage of Douglas-fir – particularly in excess of 50-60 percent -- represents greater susceptibility. Douglas-fir habitat types on south-facing slopes and drier ridges sustain more beetle-caused mortality than others.

2. Size of Douglas-fir in the stand. Usually associated with age, stand susceptibility is also reflected in size of host trees. Generally, larger trees are more susceptible. Trees less than about 16 inches d.b.h. are not as likely to be attacked successfully.

3. Age of Douglas-fir in the stand. As Douglas-fir becomes mature to overmature, it slows in growth and is more susceptible to beetles. Greater than 80 years is considered highly susceptible. Beyond 120 years becomes extreme.

4. Overall stand density. When stocking exceeds 80 percent of normal for the site, susceptibility to attack increases significantly. Dense stocking, which increases between-tree competition and provides more shaded environments preferred by beetles, increases the probability of infestation. As stocking exceeds 150 square feet of basal area, susceptibility correspondingly increases.

5. Mature trees within BI2-BI3 categories should also be identified and treated if they possess characteristics that would make them more susceptible to infestation.

Treatments selection should be based on site and stand conditions where and when they can be the most effective.

CONCLUSION

Current Douglas-fir beetle outbreaks are reducing the population of surviving mature trees within burned areas and around fire perimeters. As important, the loss of large mature trees will reduce seed sources to regenerate burned areas. Land managers should consider survey results, discussions, and management alternatives as options in deciding appropriate actions to reduce Douglas-fir beetle-

caused mortality. Forest Health Protection can provide management information for specific areas upon request. Information and survey data from specific fires is also available.

REFERENCES

Atkins, Mark D.; Les H. McMullen. 1958. Selection of host material by the Douglas-fir beetle. Bimonthly Progress Report. Canadian Department of Agriculture, Forest Biology Division Science Services. 14(1): 3.

Bentz, Barbara. 2000. Forest Insect and Disease Tally System (FINDIT) User Manual. General Technical Report RMRS-GTR-49. Ogden, UT. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 15 p.

Forest Health Protection. 2000. Survivability and Deterioration of Fire-Injured Trees in the Northern Rocky Mountains. Forest Health Protection Report 2000-13. Missoula, MT. U.S. Department of Agriculture, Forest Service, Northern Region. 49 p.

Forest Health Protection. 2002. Assessment of bark beetles and associated tree damage in areas burned in 2000-2001 wildfires. Study plan, *unpublished*. Missoula, MT. U.S. Department of Agriculture, Forest Service, Northern Region, Forest Health Protection.

Furniss, Malcolm A., M.D. McGregor, M. W. Foiles, and A.D. Partridge. 1979. General Technical Report INT-59. Ogden, UT. U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 20 p.

Furniss, Malcolm A. 1965. Susceptibility of fire-injured Douglas-fir to bark beetle attack in Southern Idaho. Journal of Forestry. 63 (1): 8-11.

Gibson, Ken. E., E. Lieser, and B. Ping 1999. Bark beetle outbreaks following the Little Wolf Fire. Forest Health Protection Report 99-7. Tally Lake Ranger District, Flathead National Forest. U.S. Department of Agriculture, Forest Service, Northern Region. 15 p.

Gibson, Ken. 2001. Douglas-fir Beetle/Fire Interactions. Forest Health Protection Trip Report TR01-4. Rexford Ranger District, Kootenai National Forest. U.S. Department of Agriculture, Forest Service, Northern Region. 9 p.

Negron, Jose F., W.C. Schaupp, K.E. Gibson, J. Anhold, D. Hansen, R. Thier, and P. Mocettini 1999. Estimating extent of mortality associated with the Douglas-fir beetle in the Central and Northern Rockies. Western Journal of Applied Forestry. 14 (3): 121-127.

Randall, Carol; Greg Tensmeyer. 1999. Douglas-fir beetle hazard rating system using the Oracle database and the Forest Service IBM Platform. Forest Health Protection Report 99-6. U.S. Department of Agriculture, Forest Service, Northern Region. 5 p.

Schmitz, Richard F.; Ken E. Gibson 1996. Douglas-fir Beetle. Forest Insect and Disease Leaflet 5 R1-96-87. U.S. Department of Agriculture, Forest Service. 8 p.